Lead Criteria Recalculated for Virginia in 1996

- EPA Published Lead Criteria Documents in 1980 and updated it in 1984.

- In 1996, Virginia DEQ conducted a literature search for new toxicity information on lead.

- After reviewing the newer literature with advisory committee and identifying acceptable, new toxicity information, DEQ recalculated the Virginia Criteria for lead and adopted it in 1997.

Virginia's Water Quality Criteria for Lead

- Used EPA's 1984 Lead Criteria Document as a basis and added additional, newer information.
- Recalculated both freshwater and saltwater criteria.

EPA Recommends Applying a "Conversion Factor" to More Accurately Express Metal's Criteria as "Dissolved"

Virginia's Recalculated Lead Criteria do not Include the Use of a Conversion Factor

Question:

- Given that there are differences between EPA's and Virginia's criteria for lead;
- are the conversion factors recommended by EPA for adjusting their criteria from a "total recoverable" to a "dissolved" criteria appropriate for use with Virginia's criteria?

Quick Review of How Water Quality Criteria for the Protection of Aquatic Life are Calculated

Summary of Methodology Used to Calculate Water Quality Criteria

1. Identify all acceptable toxicity tests and quality of information available.
2. Ensure needed variety of species in the data set to ensure wide range of species covered.
3. Develop data set of all acute toxicity data ranked by genus and species.

Criteria Methodology (continued)

4. Calculate the means of LC_{50} values for each species,
5. If hardness affects toxicity, normalize all LC_{50} values to a standard hardness level.
6. Calculate the mean of all normalized LC_{50} values for the same species to get a species mean acute value (SMAV).
7. Calculate the genus mean acute value (GMAV) for all species in the same genus.

Criteria Methodology (continued)

8. Rank all GMAVs in order of sensitivity, e.g. most sensitive = rank # 1

9. The total number of genera in the dataset and the actual GMAV concentrations for the four most sensitive genera are used to calculate the final acute value (FAV).

10. This FAV is the basis for the criteria.

The Final Acute Value is the Basis for the Acute Criteria

The acute criterion = FAV / 2

The Final Acute Value is Also the Basis for the Chronic Criteria

The chronic criterion = FAV / FACR

ACR = Acute to Chronic Raito:

$$\frac{\text{Acute value } (LC_{50})}{\text{Chronic value}} \quad \text{(from same toxicity test)}$$

FACR = mean of several ACRs determined to be appropriate, based on the pollutant's dataset

Virginia's Dataset For Freshwater Lead Criterion

Rank	Genus Mean Acute Value	Species	Species Mean Acute Value (@ hardness 50)
4	607.8	Smallmouth bass *Micropterus dolomieu*	607.8
3	296.8	Cladoceran *Daphnia magna*	323.8
		Cladoceran *Daphnia pulex*	272
2	161.7	Cladoceran *Ceriodaphnia reticulate*	255
		Cladoceran *Ceriodaphnia dubia*	102.6
1	142.6	Amphipod *Gammarus pseudolimnaeus*	142.6

Total number of genera in dataset = 16

Final Acute Value (FAV) = 98.40
The acute criterion equals the FAV/2
98.40/2 = 49.2 µg /L at a hardness of 50 mg/L $CaCO_3$ (or 118.9 µg /L @ hardness of 100)
The chronic criterion equals the FAV/17.6
98.40/17.6 = 5.6 µg /L at a hardness of 50 mg/L $CaCO_3$ (or 13.63 µg /L @ hardness of 100)

EPA's Dataset for Freshwater Lead Criterion

EPA' 1984 Lead Freshwater Water Quality Criteria Dataset

Rank	Genus Mean Acute Value	Species	Species Mean Acute Value
4	2,448	Rainbow Trout	2,448
3	1,040	Snail, *Aplexa hypnorum*	1,040
2	447.8	*Daphnia magna*	447.8
1	142.6	Amphipod, *Gammarus pseudolimnaeus*	142.6

Total number of genera = 10

Final Acute Value (FAV) = 67.54
Acute to Chronic Ratio = 51.29
CMC = e (1.273[ln(hardness)] – 1.460
CCC = e (1.273[ln(hardness)] -4.705

Why "Conversion Factors"?

Original toxicity tests that are the basis for many of the metals' criteria determined the toxicity values (e.g. LC_{50} values) using several different methods.

- **static tests, renewal tests, flow-through tests**

- **LC_{50} values were calculated based on:**
  nominal concentrations, total recoverable concentrations or other similar methods that are expected to give equivalent concentrations in toxicity tests

  Very few "dissolved" concentrations were reported in the older literature.

Many States Adopted the EPA Criteria Values as Dissolved Values **(unchanged from the EPA values)**

- **This approach assumed that all or almost all of the metal in the toxicity tests that are important to the derivation of the criteria was dissolved in the test chambers.**

- **EPA believed that this assumption might be true in some cases but not in all and could result in criteria that would be under-protective by an unknown amount.**

EPA Believes that Their Criteria Should be Adjusted to be Considered "Dissolved" Criteria

- EPA believed that a conversion factor was needed to convert the older criteria values that had been expressed as total recoverable metals to the newer "dissolved" metals terminology

- EPA developed recommended "conversion factors" to "convert" the original criteria values to dissolved values

- Conversion factors were developed for the specific metal's criteria based on the types of original data used to calculate the criteria

EPA Recommendations for Conversion Factors

- **EPA developed recommendations for conversion factors for the metals' criteria based on the type of tests that most influenced the calculation of the criteria.**

- **Conversion factors are unique for each metal's data set**

EPA conducted “simulation tests” to estimate the percent dissolved metal in water under conditions of the original, important toxicity tests

- Considered:
- type of tests; static, renewal, flow-through
- whether food was present in the test chambers,
- duration of the tests; 48-hour or 98-hour
- hardness,
- concentrations of the metals,
- other factors that might affect the percent dissolved

EPA Determined That with Some Metals and Under Some Toxicity Test Conditions, there was a Difference Between the “Total” Metal and the “Dissolved” Measurements

This difference, or “percent dissolved” formed the basis for the conversion factors.

Where Does the Metal Go?

Decrease in metal concentration from hour 1 to hour 48 or 96 might be caused by:

- Precipitation
- Uptake by test organisms
- Uptake by food
- Sorption onto test chambers

Based on the Results of These Tests, EPA Developed their Recommended Conversion Factors for the Metals

Conversion factors ranged from:

- **a low of 0.316 for chromium (III) (acute)**
- **A high of 1.0 for arsenic**

- **Most were > 0.90**

Recommended Conversion Factors for EPA's Lead Criteria

Freshwater CF (acute & chronic) is hardness variable and is given by an equation:

1.46203-[(ln hardness)(0.145712)]

@ hardness	**Conversion factor**
50	**0.892**
100	**0.791**
150	**0.730**

Saltwater CF (acute & chronic) is **0.951**

Existing Virginia Lead Criterion

Lead (mg/l)[5]

Freshwater values are a function of total hardness as calcium carbonate CaCO3 mg/l and the water effect ratio. The minimum hardness allowed for use in the equation below shall be 25 and the maximum hardness shall be 400 even when the actual ambient hardness is less than 25 or greater than 400.

Freshwater acute criterion (mg/l)

WER [e {1.273[ln(hardness)]-_1.084_}

Freshwater chronic criterion (mg/l)

WER [e {1.273[ln(hardness)]-_3.259}]

WER = Water Effect Ratio =1 unless shown otherwise under 9 VAC 25-260-140.F and listed in 9 VAC 25-260-310

e = natural antilogarithm

ln = natural logarithm

Virginia Criteria for Lead

- Some of the toxicity tests that influence the Virginia lead criteria are different from the tests that are the basis for EPA's lead criteria.

- Concern that the appropriate conversion factor for Virginia's lead criteria may be different than EPA's.

The Question (again):

- Given that there are differences between EPA's and Virginia's criteria for lead;
- are the conversion factors recommended by EPA for adjusting their criteria from a "total recoverable" to a "dissolved" criteria appropriate for use with Virginia's criteria?

DEQ's Recommended Approach

(as presented at February 2009 committee meeting)

- Follow EPA's approach to applying a conversion factor to a metal criteria, but adjusted to the data set that is the basis for the Virginia lead criteria.
- Review the original literature that directly influences the Virginia criteria for lead.
- Determine the type of measurements of lead used in the critical tests that directly influence the criteria calculations.

DEQ's Recommended Approach

(as presented at February 2009 committee meeting)

- Where needed, adjust the original test's LC_{50} values to dissolved concentrations.
- Assess if a conversion factor should be applied to the important tests' results individually, or to the finished criteria.
- Account for any differences between acute or chronic tests conditions.
- Determine whether to recalculate the criteria based on the dissolved concentrations or by applying using a conversion factor to the finished criteria.

Review of the Derivation of EPA's Recommended Conversion Factors

EPA's Advice on Applying the Recommended Conversion Factors to a State's Recalculated Criteria

- "It is probably appropriate to apply these factors not only to the national criteria but also to recalculated criteria if the recalculated criteria are similar to the national criteria. For criteria where one or more of the tests with the four most sensitive genera was based on a dissolved metal, test-specific adjustment and recalculation of the FAV is required."

- From: Derivation of Conversion factors for Dissolved Saltwater Aquatic Life Criteria for Metals, Lussier, S.P and W. S. Boothman draft report (3/31/1995) to the Office of Water

Two Reasons to Consider Deviation from EPA's Recommended Conversion Factors:

1. If any of the important tests for the four most sensitive genera were based on dissolved concentrations, then test-specific adjustments and recalculation of the FAV is warranted.

2. If any of the important tests for the four most sensitive genera were based on significantly different conditions than those that form the basis for EPA's criterion, some adjustment could be considered.

DEQ's Review

1. **Identified all important toxicity tests that influence the FAV or final acute to chronic ratio.**
2. **Obtained copies of all original papers for the these important tests that are unique to the Virginia dataset.**
3. **Reviewed these papers to determine how the metals were measured, how the toxicity values were calculated and the type of tests involved.**
4. **Compared these to the type of tests that form the basis for the EPA FAV and final acute to chronic ratio.**
5. **Determine if there are any significant differences between EPA's and Virginia's datasets.**

None of the LC_{50} Values in Either EPA's or Virginia's FAV Dataset Were Based on Dissolved Lead Measurements

LC_{50} values in the Virginia dataset were based on nominal concentrations or measurements EPA considers to be equivalent to total recoverable concentrations.

This Suggests That There are no Significant Differences in the Types of Data That Form the Basis for Either of the EPA and Virginia Criteria for Lead.

The only differences are due to the additional toxicity data in the Virginia dataset which resulted in the calculation of different FAV values and criteria concentrations.

Development of EPA's Conversion Factor for Freshwater Lead Criterion

The important toxicity tests that were important in the derivation of the EPA freshwater criterion for lead were;

- flow-through,
- renewal,
- 48-hour static (fed and unfed)
- 96-hour static tests.

This is also true for the Virginia data set.

EPA's Recommendations for the Acute Criterion Conversion Factor

(Freshwater)

"Because all the acute tests used in the derivation of the criterion were unfed tests and the percent dissolved is higher in the unfed tests the recommended conversion factor for the CMC is 0.890 which is the average of 1.027, 0.864, and 0.778"

(based on different test conditions that represent conditions in the original toxicity tests; all at hardness = 50)

EPA's Freshwater Chronic Criterion

- Of the five freshwater chronic tests used in the derivation of the EPA criterion, three were renewal and two were flow-through tests (all were fed).

- Recommendation CF for the chronic criterion is based on the tests containing food
- Recommendation CF for the chronic criterion is:
  0.895 at hardness of 50
  0.690 at hardness of 200

Because the Data for Both the Acute and Chronic Conversion Factors Were so Similar, a Single Conversion Factor Was Recommended for Both Criteria

EPA'S Derivation of Recommendation for CF for Lead in Freshwater

Mean of dissolved fractions from:

Unfed tests:
1-hour (1.027)
48-hour (0.864)
96-hour (0.778)

Mean = 0.890 (at hardness=50)

Fed tests:
1-hour (0.947)
48-hour (0.843)

Mean = 0.895 (at hardness=50)

1-hour (0.731)
48-hour(0.648)

Mean = 0.690 (at hardness=200)

Two Tests in Virginia's Dataset Did Contain Some "Dissolved" Measurements of Lead.

Spehar and Fiandt (1986) (new data for fathead minnow and *Ceriodaphnia):*

- Calculated the LC_{50} values based on total metals measurements
- Also provided some additional information on the relationship between nominal and dissolved lead
- reported that dissolved lead was 0.75 $\pm$ 0.14 of total lead at a hardness of 165.
- EPA's recommended CF is 0.718 at hardness 165 (the test conditions)

Coughlan and Gloss (1986) (new data for smallmouth bass):

- Calculated the LC_{50} values based on nominal concentrations
- Also provided graphical information on the relationship between nominal and dissolved lead.
- At a nominal LC50 value of 2.8 mg/L the dissolved concentration is approximately 1.25 ppm (dissolved fraction of about 0.45)
- EPA's recommended CF is 0.7292 at hardness 151 (the test conditions

EPA's and Virginia's FAV Dataset Based on the Same Types of Test Conditions

EPA FAV Dataset:

- flow-through
- Static, renewal
- 48-hour static (fed and unfed)
- 96-hour static tests

Virginia's FAV Dataset

- flow-through
- Static, renewal
- 48-hour static (fed and unfed)
- 96-hour static tests

EPA's and Virginia's Chronic Toxicity Dataset are Based on the Same Types of Test Conditions

EPA Chronic Dataset:

- **2 flow-through tests**
- **3 renewal tests**

Virginia's Freshwater, Chronic Dataset:

- **2 flow-through tests**
- **3 static tests**
  (above same as EPA's)
- **+ 1 new flow-through test**
- **+ 1 new renewal test**

EPA's derivation of the Conversion Factor for Lead in Saltwater

- In most 48-hour tests, lead was >90% dissolved with a mean ratio 90.6% and in all of the 96-hour flow-through tests lead was >95% dissolved with a mean of 99.7%).

- Recommended CF as the mean of static and flow-through tests = 0.951 for saltwater.

EPA's derivation of the Conversion Factor for Lead in Saltwater

- EPA conducted acute toxicity tests generating high quality data for both dissolved and total recoverable metals measurements
- *Mytilus edulis* and *Mysidopsis bahia*
- 48–hour static, unfed tests
- Flow-through, fed tests

Development of EPA's Conversion Factor for Saltwater Lead Criterion

The toxicity tests that were important in the derivation of the EPA saltwater criterion for lead were static tests, and used nominal concentrations to calculate the reported the LC_{50} values.

Virginia's Saltwater FAV Dataset is Similar to EPA's

Of the four most sensitive genera in the EPA and Virginia databases, three genera are the same and are based on the same toxicity studies.

None of the LC_{50} values for any of these genera are based on dissolved lead concentrations.

- Virginia's data set differs as follows:
- One additional new study was located for the Dungeness crab, but LC_{50} value was not based on dissolved concentrations
- The GMAV values for some of the genera were recalculated to account for control mortality, which resulted in the GMAV ranking changing for some of these genera:
- *Amplesca abdita* became rank # 3 and quahog clam became rank # 4

The Virginia saltwater lead chronic criterion is based on the same FACR as the EPA criterion.

Conclusion 1:

Virginia's datasets for freshwater and saltwater criteria for lead do not contain any LC_{50} values that are based on dissolved lead concentrations.

Conclusion 2:

EPA's recommended conversion factors for lead are based on simulation tests that are appropriate for the test conditions that were used in the important tests that form the basis for both EPA's datasets and Virginia's data set.

Conclusion 3:

Because there are no significant differences between the types of tests that are important to the Virginia criteria for lead and those that are important to the EPA lead criteria dataset, the conversion factor developed by EPA for their lead criteria can be considered appropriate for application to Virginia's criteria also.